EPA. 2000. Stressor Identification Guidance Document. U.S. Environmental Protection Agency, Office of Research and Development. Document # EPA-822-B-00-025. 228 p.

This report is quite useful so I have made a fairly detailed summary of its contents.

The report develops a formal process and structure for using science to identify and verify stressors to meet objectives of the Clean Water Act.

The Stressor Identification process (SI) kicks in when a biological impairment is detected. The SI process entails critically reviewing available information, identifying possible stressors that might explain the impairment, analyzing those stressors and their context, and drawing conclusions about which stressor or stressors are causing impairment. The result can be translated into management action and monitoring the effectiveness of management.

The process proceeds in 4 steps:

1. identify and characterize the impairment (e.g., species decline, range contraction, species invasion, increased incidence of disease or lesions, increased body burden of contaminants, reproductive impairment, etc.);
2. Listing the candidate causes/stressors;
3. Assembling and analyzing new and previously available evidence that could link the stressor to the impairment;
4. Decide which stressors are most likely to have caused the imparement.

There is also advice on how to deal with situations where no clear determination of which stressors are important can be made.

The first step in the SI process is to develop a list of candidate causes, or stressors, that will be evaluated. This is accomplished by carefully describing the effect that is prompting the analysis (e.g., unexplained absence of brook trout). The impairment needs to be described in terms of its nature, magnitude and extent (both geographic and temporal). Broadscale impairment should be broken down into discrete impairments or effects, as each may result from a different stressor. The next step is to gather available information on the situation and potential causes. Evidence may come from the case at hand, other similar situations, or knowledge of biological processes or mechanisms. The outputs of this initial step are a list of candidate causes and a conceptual model that shows cause and effect relationships. Initially, the list of candidate causes should include everything anyone thinks is important and be trimmed down later as analysis proceeds.

Conceptual models need to be developed to show how stressors are linked to impairment. Conceptual models provide a good way to communicate hypotheses and assumptions about how and why effects are occurring. Models can also show where different causes may interact and where additional data collection may provide useful information. A pictorial, poster-style conceptual model may be useful to introduce the ecological relationships. A box and arrow diagram can be used to show details of the relationships among stressors, receptors, and intermediate processes.

Flow Chart of the SI Process:

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In the analysis step, the primary inputs are the list of candidate causes and the associated conceptual models. Other inputs include data and information that come from the case at hand, from similar cases, the laboratory, and the literature that synthesizes biological and ecological knowledge. This information is converted into causal evidence in four general categories of increasing reliability in terms of determining cause and effect:

1. associations between measurements of the candidate causes and effects;

2. associations between measures of exposure at the site and measures of effects from laboratory studies;
3. associations of site measurements with intermediate steps in a chain of causal processes; and
4. associations of cause and effect in deliberate manipulations of field situations or media.

Obtaining measurements that allow application of any of these approaches can be challenging. The report offers a variety of ideas about how to develop quality information on cause and effect.

The SI process may be iterative; if the stressor is not adequately identified in the first attempt the process repeats using better data until the stressor is successfully identified. Completing the SI process is helpful even without adequate data because the exercise can help target future data collection efforts.

Once stressors are identified they may be characterized and their likely importance determined. The report discusses three approaches to focusing in on the most significant causes:

1. Elimination of alternatives. This is a powerful approach when the situation is relatively straightforward and data are statistically powerful. However the report includes on serious logical fallacy: “If a set of possible causes has been identified, once all but one alternative has been eliminated, the remaining hypothesis must be true”. This was the Baconian approach to scientific inference and has been clearly shown to be incorrect as it assumes all possible causes have been considered and the information and analyses used to refute other causes are without uncertainty. However, subsequent discussion of elimination of alternatives covers the difficulty of applying the approach with the kind of absolute certainty needed to satisfy the Baconian approach. In most cases, any elimination of causes will only narrow the list of potential causes.
2. Application of diagnostic protocols. This approach differs from the one above in that it is based on the presence of certain indicators rather than their absense. The approach assumes that causal effects are well enough understood that specific protocols have been developed for their detection and that these are generally accepted.
3. Weight of evidence. This analysis organizes information so that the evidence that supports, or doesn’t support, each candidate cause can be easily compared and communicated. When there are many candidate causes or when evidence is ambiguous, strength of evidence analysis is more useful than elimination of alternatives because it identifies the alternative that is best supported by the evidence.

Weight of evidence analysis rests on ten considerations. The first four, *co-occurrence, temporality, biological gradient,* and *complete exposure pathway* draw primarily on associations derived from the case itself. These considerations form the strongest basis for causal inference. The next two considerations, *consistency of association* and *experiment* can be based on the case at hand but may draw from similar situations. The next four considerations, *plausibility, specificity, analogy, and predictive performance*, combine information from the case at hand with experiences from other cases or test situations, or from knowledge of biological, physical, and chemical mechanisms. These considerations corroborate and supplement the basic observations from the case. The last two considerations, *consistency* and *coherency of evidence*, evaluate the relationships among all available lines of evidence.

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Flow Chart Showing Application of the 3 Approaches to Characterization of Causes

Co-occurrence refers to the spatial co-location of cause and effect. *Temporality* refers to the temporal co-occurrence of cause and effect (effect must never precede cause). *Biological gradient* refers to the presumption that any effect should increase with increasing exposure to the cause. However, assessment should be sensitive to the possibility of non-linear responses. *Complete exposure pathway* refers to the need for a complete chain of connection between cause and effect. Any break in the chain makes any causal relationship unlikely.

Consistency of association means that the hypothesized cause and effect relationship has been observed in other locations or has been observed in the past at the present location. *Experiment* refers to manipulations of presumed cause(s) associated with observation of hypothesized effect(s). Experiments may be conducted in the laboratory or in the field.

Plausibility refers to the logical likelihood of the cause/effect relationship given our understanding of biological/ecological mechanisms and our understanding of typical response levels to stressors of the sort being investigated. That is to say, is the response too strong or too weak given what we know in general about responses to this kind of stressor at the presumed level of exposure. *Analogy* considers whether the hypothesized cause/effect relationship is consistent with other well known and analogous relationships. For example, a new and relatively unstudied pesticide may be presumed to have similar effects to other pesticides with similar chemical characteristics. *Specificity of cause* refers to circumstances where effects are only known to be associated with one or a few very specific causes. *Predictive performance* refers to situations in which a cause has predicted effects that have not previously been observed. If these can be shown to occur in the case it strengthens the evidence for a particular cause. *Consistency of evidence* refers to whether all lines of evidence in a particular case point to a particular set of causes. If different lines of evidence point to different causes it makes it much more difficult to confirm a particular cause.

In cases where measurement data are inadequate for a completely objective identification of causes and their relative importance, expert judgment may provide an efficient and acceptable way to characterize the importance of stressors. However, this approach can be difficult if the situation is highly contentious and conflict laden. The approach was not discussed in detail.

The table below (Table 4-3 in the report) illustrates a format that can be applied to specific cases. Weight of evidence criteria are listed in the left-hand column of the table while the other columns presents results for a candidate cause. Rows show the appropriate number of +, -, or 0 symbols associated with the strength of evidence for each criterion for each candidate cause. Supporting narratives should describe how the scores were obtained from the evidence. We do not recommend adding up the scores for each candidate cause as this would imply that each criterion is of equal importance. (Note, however, that if an independent weighting of criteria has been performed, adding scores could be used as a guideline to relative importance.) In difficult cases, it may be valuable to compare the evidence for each individual consideration across the candidate causes. Particular attention should be paid to negative results, which are more likely to be decisive.

TABLE: Matrix for evaluating weight of evidence criteria against evidence for each potential cause.

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Once causes have been identified by this process an assessment of their uncertainty must be completed. For assessments that are quantitative statistical techniques may be used to assess uncertainty. In most cases, unquantified uncertainties will dominate. In addition, most causal inferences are based on the strength of evidence, so that no single source of uncertainty characterizes the uncertainty concerning the conclusion. As a consequence, uncertainty must be characterized qualitatively. Any qualitative judgment should be accompanied by a list of major sources of uncertainty and their possible influence on the results.

In many if not most cases, there will be significant uncertainty concerning the relative contributions of alternative causal factors. In such cases, it is necessary to determine whether the evidence is sufficient to justify a management action. Standards and criteria for establishing causation are not generally agreed upon. In particular, there is no consistent standard for adequacy of proof. Such decisions may be based on considerations such as the cost of remediation and the nature and magnitude of the ecological injury. Ideally, *a priori* criteriashold be developed for deciding whether the characterization of a cause is sufficient for management action.

The report illustrates the application of the method with two case studies. One of these, the Scioto River in Ohio, is a complex case involving non point agricultural runoff, industrial pollution and significant physical alteration of habitat. Although not an analogue of the Delta it does give a good illustration of how the method can be used to characterize and evaluate potential stressors in a complex situation.